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BEEF HOUSING STUDIES - WORKING REPORT I

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1. OBJECTIVES

1.1 The purpose of this note is simply to present a progress report and some initial conclusions for discussion and comment.

1.2 The initial proposal of the Livestock Group was that a survey be made with the object of identifying some of the contrasting characteristics of "good" and "bad" units. The terms good and bad were to be subjective reports or assessments of animal performance, based on the incidence of respiratory disease and on the rate of liveweight gain; the emphasis in the survey was to be on building characteristics. Hopefully, the survey would enable the Lands Arm to arrive at design criteria that would ensure acceptable internal environments under most (weather) conditions.

In discussion it was accepted that housing simply to modify the thermal environment of animals fed something more than a maintenance ration could probably not be justified in the Eastern Region. Nevertheless, considerations such as ease of feeding and handling, and prevention of poaching of the ground, were likely to be factors that would ensure the continued housing of beef animals.

In order to make a contribution over and above similar surveys in the past, it was suggested that the present study should include some assessment of 'ventilation'. The interest here is in both the overall, air change rate of a large, relatively open, naturally ventilated house and the more relevant local rate of air renewal at animal level (which provides some measure of the efficiency of the distribution of the incoming air).

With these thoughts in mind, it was concluded that detailed studies in a small number of houses would prove more informative than a superficial study of a larger number of houses.

1.3 The initial field work was begun with strictly limited objectives. These were - firstly, to devise a technique for the comparison of the ventilation characteristics of beef units - secondly, if possible, to arrive at some absolute measure of the ventilation characteristics.

2. FIELD WORK

2.1 To understand the thinking behind the field work objectives, it is necessary to be aware of some of the difficulties involved in ventilation studies. The use of tracer gas techniques is regarded as axiomatic at this point in time. The standard procedures employed in the past have been concerned with enclosed structures, commonly of small size, and commonly with ventilation by natural infiltration only. Ventilation rates of the order 2-3 air changes per hour,

that is volume flows of the order 2-3 room volumes per hour, would be typical. The transfer is not readily made from procedures found useful in such structures to larger, more open structures, freely accessible to the natural wind, subject to the vagaries of wind speed and direction, with volume flows commonly an order of magnitude greater under moderate wind speeds, and with air inlet and outlet areas ill-defined and subject to change with the variations in wind direction and the eddying flow induced by the building itself and other, nearby obstacles to the wind flow.

The Standard tracer methods are

(a) Rate of Decay

This involves an initial uniform concentration of tracer throughout the building. With perfect mixing of the incoming air, the tracer concentration decay curve at a given sampling point is then exponential.

(b) Equilibrium concentration

The tracer is emitted continuously at a uniform rate and if conditions are steady, the concentration at any point in the building approaches a steady state value.

(c) Transfer Index

This involves the determination of the time integral of the tracer concentration at one point, following the liberation of unit volume of tracer at another.

(d) Steady Concentration

Tracer is injected at one point and the concentration measured at some other point. The tracer injection is controlled, preferably automatically, so as to give a steady, known concentration at the measurement point.

In many farm buildings, and in beef housing in particular, only some variation of the Transfer Index procedure would appear to offer a viable modus operandi.

2.2 The instruments available meant that spot indications had to be obtained during flying visits, rather than any continuous recordings.

Observations could be made of temperature, humidities and air velocities both inside and outside the house, together with wind direction outside and with some visualisation of the air flow inside (by smoke and bubbles).

However, chief interest lay in the use and interpretation of measurements that could be made using nitrous oxide as a tracer gas and an infra-red gas analyser to monitor tracer concentration.

HOUSE 1

At the first house visited, House 1, the mean free external wind speed at 2 metres over the period of the investigations was 3.8 m/s (8.5 mph). Typically the wind direction was oblique to one of the longer sided, space boarded walls and some drift of air could be detected across the house at animal level, in addition to fluctuating recirculation patterns, opposed at times and in

places to this general air movement in response to wind pressure. Typical air velocities in the body of the house eg in the central feed passage were of the order 0.5 m/s (100 f/m).

Release of tracer gas was made at the windward, internal wall of the house and the air in the central feed passage was sampled. This air was brought to the analyser through polythene tubing attached to an internal pump.

Tracer release rates up to 40 litres per minute could be monitored with a flow meter. Maximum sampling rates were 2 litres per minute. With continuous release of nitrous oxide for periods up to 2 minutes, no significant amounts of tracer could be detected at the sampling point within a subsequent 10 minute period (scale range 0-200 ppm).

Release of the tracer at these rates under the prevailing situation of wind and internal air movement was obviously inadequate, even though visualisation of the air movement showed a general drift from the release point to the sampling point. This meant a "Transfer Index" as such, could not be established. Evidently a sudden, gross release of tracer was required, the amount of which could not be monitored.

The procedure adopted now was to release nitrous oxide direct from a cylinder, until a concentration approaching (or in excess of that giving a full scale deflection on the lower range of analyser ($\geq$ 200ppm) was shown at the sampling point. The rate of decay of concentration was then followed in the conventional way, through dial indications of concentration at one minute intervals (or less).

The interpretation of the measurements one was forced into is obviously difficult. When a conventional analysis was made of the change of observed concentration (at the sampling point) against time, as would be done for the Rate of Decay method, it was found that the initial rate of decay was exponential. The fall off in concentration was subsequently interrupted by a short-lived, increase in concentration (arising from recirculation currents or external gusts) and the exponential rate of decay at the sampling point was then resumed. In this particular instance, both exponential decay rates had the same numerical value. Under the assumptions and conditions of the rate of decay method, the "ventilation rate" in both instances would have been interpreted as 42 air changes per hour. We can perhaps interpret this result as a local "air renewal rate of unit volume at the sampling point" of 42 volume changes per hour. Assuming the internal air velocity measurements indicated the magnitude of the oblique, bulk drift of air across the house under external wind pressures, then the expected "ventilation rate" would have been of the order 40 air changes per hour.

The results of this simple evaluation of the results encouraged us to believe that we might at least have some basis for comparison of the air renewal rate in different houses, even though a precise physical interpretation of the measurement remained uncertain. One could envisage different results with different sizes (duration of release) of the tracer puffs and with situations where the external wind did not produce such a steady drift across the house, and where recirculation, as distinct from through circulations, tended to predominate.

HOUSE 2

The second house visited was buried within a complex of other farm buildings. The free, external wind at 2 metres was blustery with frequent changes in speed and direction. During the period of the Study the wind was directed obliquely to the only freely exposed side of the building, and the mean wind speed was 3.5 m/s (8 mph).

The patterns of air movement were made visual by smoke and bubble generators and sampling points were established on the downwind side of each of the 6 pens into which the house was divided. The results obtained by the procedure of releasing tracer gas directly from the cylinder until a full scale deflection was obtained at analyser are shown in Figure 1 where a conventional Rate of Decay analysis is employed.

The fluctuations about an overall decrease in concentration with time are possibly to be explained as being due either (or to both) recirculation currents, or the effects of gusts in the ventilating air stream. One can imagine the penetration of the travelling puff of tracer by a faster moving parcel of air and a possible, subsequent recovery of concentration at the sampling point when the effects of the parcel (or small jet) of air have been dissipated by entrainment.

What we have is a short lived plume (a puff) extending from the cylinder at the release point (where the issuing jet should ensure rapid turbulent mixing), to the sampling point. The leading edge of the puff is ignored, by the requirement of an initial sample concentration $\geq$ 200 ppm, and what we observe involves both the traverse of the puff across the sampling point and the dilution and expansion of the puff by eddying motions and entrainment. The release of the tracer in these early studies was commonly in the direction of the sampling point, so that there was some initial momentum given to the puff in the direction of the sampling point. The use of the term "air renewal rate" in this note does not distinguish between dilution of the tracer by air arriving directly from outside the house and dilution by recirculating and eddying air currents with a longer life history within the house.

There are obvious gradations in the complexity of the Rate of Decay curves observed at different points in the house.

Run 4, over Pen 4, represents perhaps the simplest curve. Under the assumptions and conditions of the Rate of Decay Method, the "ventilation rate" was here 22 changes per hour. We take this to imply a "local air renewal rate" of unit volume at the sampling point of 22 volumes per hour.

In run 3, over pen 3, (up-wind of pen 4) we find local air-renewal rates of 27 volume changes per hour at the beginning and end of the sample period, and an air renewal rate several times this value (109 volume changes per hour) over a 1 minute period, between minute 3 and 4; subjectively one could link gusts felt near the space boarding with subsequent rapid changes in concentration shown by the analyser, and this rapid increase in decay rate in the middle of the run is presumably to be interpreted in this way.

One must conclude that with overall sampling times of the order 10 minutes or less, air movement fluctuations over the period of a minute or less are

important and that wind measurements should reflect this in some way, in addition to conventional longer period mean winds measured over the total duration of the visit - a period of a few hours.

Run 1, over pen 1 at animal level, shows some rapid initial fluctuations and recovery of tracer concentrations over the first 3 minutes. Over a central period of 5–6 minutes, there was a steady "local air renewal rate" of 16 volume changes per hour and a subsequent increase in the rate of decay of concentration at the end of the run.

Run 2, over pen 2, shows a rapid initial decrease in concentration, at a rate comparable to, but greater than those found in the other, upwind pens of the house. There is no recovery of concentration, but there is a decrease in the rate of decay at the end of the run.

The conclusion begins to emerge that the results obtained by the tracer technique in the natural ventilation situation are greatly dependent on the minutiae of the wind structure over the period of the detailed observations.

Run 5, over pen 5, gives "local air renewal rates" less than those found over the upwind pen 2; a similar fall off in "local air renewal rate" is found in pen 4, when comparison is made with the results over the upwind pen 3.

Pen 6 was anomalous in this respect. An initial concentration $\geq$ 200 ppm suddenly fell away. This is attributed, in part to a demonstrable entry of air at the downwind eaves and space boarding, due to the complexities of the roof structures of the unit and adjacent buildings.

The results of the study this far have been presented in some detail so that some of the difficulties may be appreciated by the reader. Not only is there a problem in summarising the results obtained at any one sampling point, but also in the broader problem of summarising the results at a network of sampling points within a house, in order to say something of the characteristics of the house. Some replication of the observations would appear essential; further studies to cover different ranges of wind speed, direction and gustiness would seem necessary.

On a second visit to House 2, the mean external wind speed over the period of the internal measurements was 2.3 m/s (5 mph). The wind direction was 260° - 300°.

Repeated observations were made across pen 5. The results are shown in Figure 2.

If one omits consideration of the initial rapid change of concentration, then in 3 of the 4 sets of data, some measure of consistency is obtained with "local air renewal rates" of 11, 14 and 14 volume changes per hour.

HOUSE 3

The third house visited was set in a natural frost hollow. The mean free wind over the period of observations was 3.6 m/s (8.1 mph).

Having established the pattern of internal air movement, local air renewal rates were determined across an upwind pen for tracer release times of 1, 3 and 5 minutes.

minutes.

A resultant, practical observation is that a fresh cylinder should be used for each release, since with repeated release from the same cylinder, the cooling, an expansion of the nitrous oxide leads to icing of the valves and cylinders, and a restriction of the flow.

A 5 minute release of tracer led to a tapering output from the cylinder due to icing, and the fluctuations in concentration observed were more marked then with the 1 minute and 3 minute releases, which were the same for all practical purposes - see Figure 3.

The "local air renewal rates" observed after an initial fall off in concentration had occurred were of the order 50 volume changes per hour.

The rates found over 2 downwind pens were 51 and 73 volume changes per hour respectively.

3. DISCUSSION

3.1 The role of the site.

The emphasis to be given to the building was accepted by all in initial discussions. Visits to farms were enlightening, since they immediately demonstrated that the problem of defining the characterstics of houses with "good" and "bad" animal performance could not be restricted simply to the design features of the house.

If one accepts that animal performance can be closely related to the internal environment, which in turn follows from the ventilation flow and its distribution, then in the naturally ventilated house, the ventilation achieved is a function both of the house and its siting.

It is important to recognise the significance of such a statement, even though it may be made on the basis of quite limited field data. It suggests that there may be no such thing as a "standard" beef house, or, if standard houses must be designed and produced for sound economic reasons, then their siting in individual situations must not be done simply on the basis of convenience, either in respect of other farm buildings or ease of access, but should have close regard to local topography and other obstacles to the free wind.

The first house visited, a house with good animal performance despite the location of a feed barn at one end, was situated close to the brow of a hill.

House 2, a house with poorer animal performance, was buried within a complex of older farm buildings which met the beef unit directly on 2 sides. Other buildings were to be found across a yard on the third side, and on the fourth side, an embankment up to 2 metres in height was located across a 4 metre roadway alongside the unit. The height of the beef unit roof was deliberately kept low by planning restrictions, which required that roof should not protrude above other, pre-existing buildings.

House 3, again a house with poorer animal performance, was a small, rectangular building, well separated from other buildings but situated in a natural hollow, with rising ground on 3 sides.

As a general principle one might suggest that beef units do not need topographic or local shelter; they should be sited to obtain the maximum air movement through them in the critical, light wind situations, where removal of the heat and moisture loads placed on the building air by the animals may be primarily by stack effect.

3.2 Ventilation Results

Some basis for the comparison of the rate of air movement within and between naturally ventilated animal houses does appear to be developing from the "local rate of air renewal measurement", even though the precise interpretation of what is being measured is open to discussion.

Under the comparable wind speeds prevailing during the initial visits to each of the 3 houses (approximately 3.5 m/s or 8 mph), a comparison of "local air renewal rates" measured across pens would suggest that there is little to choose between respective house design features under such winds and their pressure effects. A "local air renewal rate" of 40 volume changes per hour found in House 1, the better performance house, could be considered typical of the minimum values found in the other, poorer performance houses.

The decrease in "local air renewal rates" found across the downward pen 5 on the second visit to House 2, was substantial - 36, 11, 14, 14 volume changes per hour compared with 44 volume changes per hour on the first visit. The mean, external wind speed during the second visit was 2.3 m/s (or 5 mph).

Greater practical interest must therefore lie in the light wind ventilation situation, than in the ventilation under strong winds. One might suggest that only in the strong wind situation should directional effects and gustiness be of significance.

We cannot in fact simply extrapolate from the strong wind to the light wind situation, since the physical processes effecting the ventilation change, from primarily wind pressure to primarily stack effect, at an external wind speed of around 1.5-2.0 m/s (3-4 mph) for the freely exposed house. This critical value of the mean free wind speed will of course be higher for the more sheltered house.

A linear relationship was suggested by Dick, from his observations, for the air change rate of human houses. In algebraic terms, an expression is suggested of the form:-

$$R = a + bv$$

where R represents the ventilation rate
a, b represent constants
v represents the free, external wind speed

The inferences drawn here, for animal houses, are that the constant, a, representing the ventilation due to stack effect, must be a function of stock density in addition to the resistance to air flow imposed by inlet and outlet design and separation; the constant, b, the slope of the line relating ventilation rate to wind pressure effects, is very much a function of the site, in addition to inlet and outlet characteristics. Not only will the slope of this line vary from site to site, but the value of the free wind at which the change over occurs from ventilation by wind pressure to ventilation by stack effect will vary from site to site, being higher for the more sheltered site.

One role of the site is to determine the frequency of the onset, and the duration, of light winds which imply ventilation primarily by stack effect, and "local air renewal rates" determined primarily by recirculation currents within the house. A complementary requirement is information on the occurrence of such situations, that is a probability distribution of free wind speeds on the site.

Presumably, since we cannot avoid the light wind synoptic situation, building design should take as a minimum condition that ventilation should always be adequate under stack effect alone.

4. RECOMMENDATIONS

4.1 Design procedures should give maximum emphasis to adequate air flow under stack effect and less emphasis to sheltering of the animals from the wind.

As a tentative suggestion "local air renewal rates" of 15 volume changes per hour might be set as a desirable minimum.

4.2 Standard design, "package deal", houses may still be regarded as acceptable, provided siting of the house is acknowledged to be important.

In the limit, wind surveys on potential sites may be considered desirable to identify an optimum choice between alternatives.

The intepretation of such surveys would require further work. Assuming that nothing more sophisticated than once daily observations of run of wind are likely to be obtained in the practical run of the mill advisory situation, then a procedure would be required to break such observations down into meaningful data for animal housing.

4.3 Further field studies to develop the "local air renewal rate measurement" are perhaps justified, if only to provide a broader base on which to recommend standard procedures.

i. The weighting of the tracer decay rates observed at any one point, according to their duration within any one sampling period, would appear to offer one method of averaging results at a given point.

ii. Multipoint tracer release and sampling could perhaps lead to smoother observed decay rates, though there would be practical difficulties in an occupied animal house. Such a procedure could produce a single figure of the "local air renewal rate " of the house as a whole.

iii. Sampling in the vertical and not simply in the horizontal is possibly of interest.

iv. Some work is required to establish the relation between free wind speed (and direction) and air velocities close to space boarding both outside and inside the house. This is needed to amplify the wind tunnel results of NIAE Silsoe, which has been reported for one board width and spacing.

Ideally, some further instrumentation would be required to do this. As a minimum, simultaneous recording of 2 wind sensors would be required. Such apparatus would also be relevant to further exploration of the "local air renewal rate" and the role of gusts in this.

Costs envisaged here would be of the order £1000. Subsequently the wind sensors would be suited for general advisory work. The recorder would be of a general type, suitable for use in other environmental studies.

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FIGURE 1 HOUSE 2 PARKFARM WOBURN 13/2/73

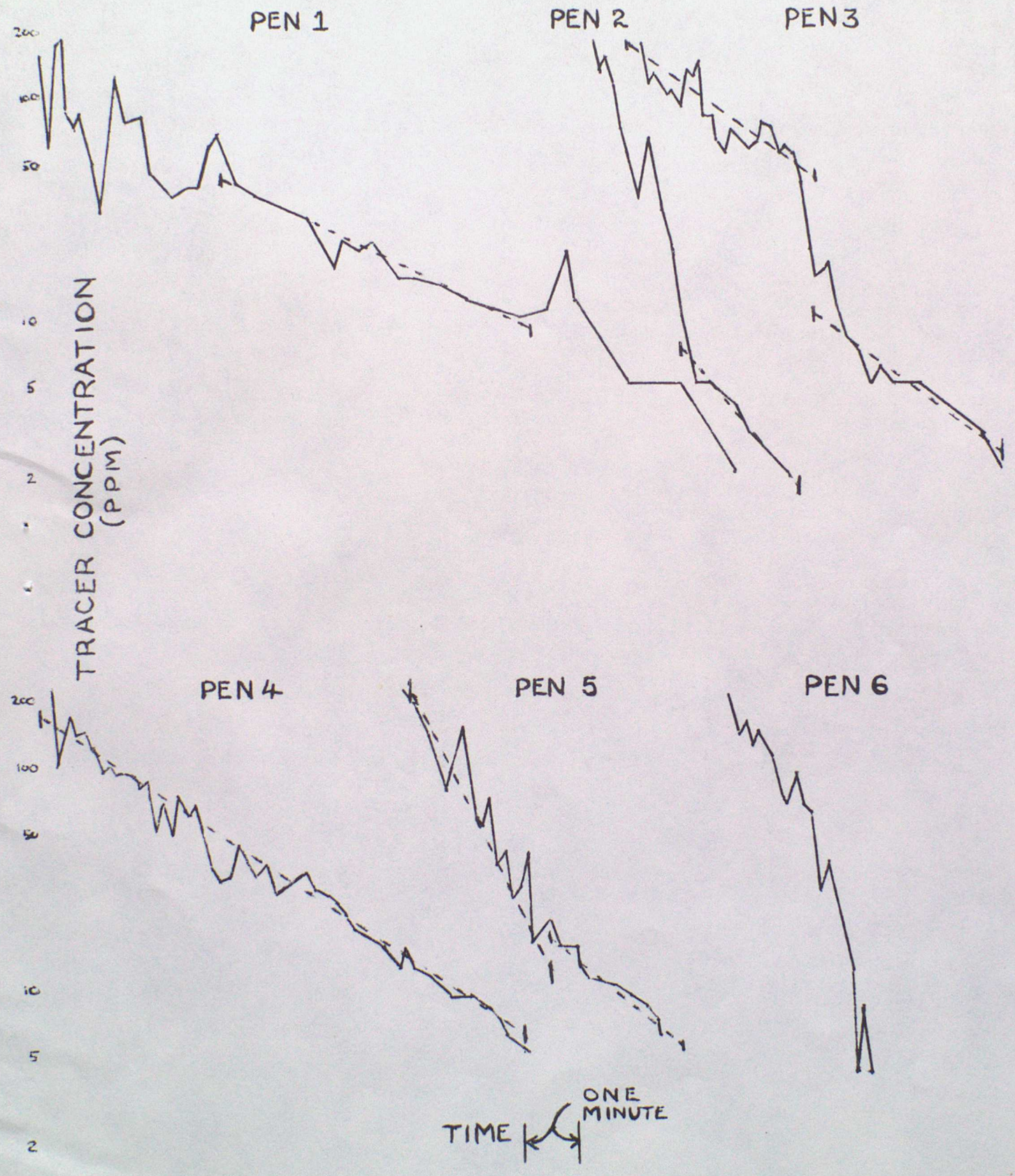

FIGURE 2 HOUSE 2 PARK FARM WOBURN 20/3/73

ALL MEASUREMENTS ACROSS PEN 5

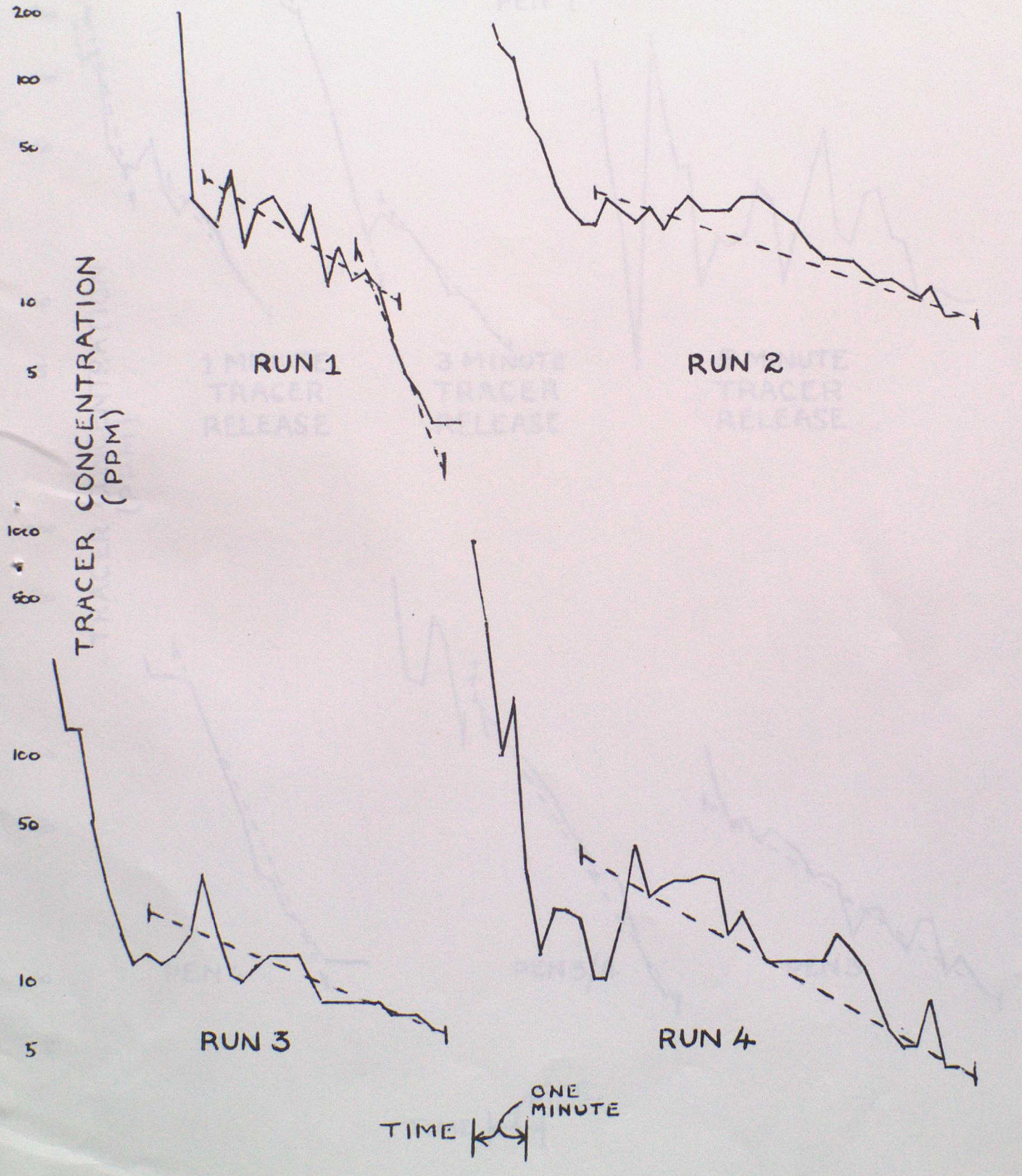

FIGURE 3 HOUSE 3 HEATH FARM SHELFORD 20/2/73